Application of multi-isotope ratios to study the source and quality of urban groundwater in Metro Manila, Philippines

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Table 1: Analytical results for water samples from Metro Manila, collected between 26 and 30 May, 2006

I.D.	Altitude m, a.m.s.l	Well depth m	pH	Cond µS/cm	Temp °C	Na^+ mg/L	K^+ mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Cl^- mg/L	SO_4^{2-} mg/L	NO_3^- mg/L	As µg/L	Cd µg/L	Pb µg/L	δD-H_2O ‰	$\delta^{18}O$-H_2O ‰	$\delta^{34}S$-SO_4^{2-} ‰	$\delta^{18}O$-SO_4^{2-} ‰	$^{87}Sr/^{86}Sr$
Rainwater																				
M15	3		5.3	25	25	0.9	0.4	0.8	0.1	1.9	3.0	1.2	0.4	*u.d.*	2.0	-34.4	-6.0	*n.d.*	*n.d.*	*n.d.*
River water (Pasig River and its tributary)																				
M11	80		8.2	318	32	14.1	7.4	36.1	8.0	8.7	12.8	10.7	4.2	*u.d.*	*u.d.*	-42.6	-6.5	5.3	6.0	0.70566
M12	9		7.4	561	33	26.1	7.8	39.2	10.1	25.8	12.8	1.1	4.4	*u.d.*	0.3	-37.7	-5.9	9.6	7.4	0.70544
M13	9		7.8	3760	33	601.2	26.5	31.7	79.8	1082.6	144.8	21.0	2.7	*u.d.*	*u.d.*	-17.9	-2.8	20.7	8.7	0.70790
M14	5		7.9	14860	32	2760.6	101.2	86.2	346.6	5187.0	676.8	70.0	*n.d.*	*u.d.*	0.2	-19.4	-3.3	21.7	10.0	0.70895
Shallow groundwater (2-122 m in depth: dug and hand pumping wells)																				
M2	6	122	7.8	582	32	44.1	12.5	47.0	18.2	10.6	8.9	1.0	8.5	*u.d.*	0.2	-52.0	-7.9	4.6	7.2	0.70464
M4	3	122	7.8	4200	31	426.8	53.0	225.7	91.3	1023.1	116.4	6.9	13.7	*u.d.*	0.1	-46.7	-7.2	23.9	12.9	0.70543
M6	6	70	8.1	633	31	82.6	28.9	28.0	8.9	22.4	20.0	1.0	22.5	*u.d.*	0.1	-48.8	-7.5	11.7	12.9	0.70645
M8	2	43	7.8	856	29	107.1	13.8	45.1	19.3	49.9	35.4	1.0	7.1	*u.d.*	0.6	-42.8	-6.4	12.2	14.4	0.70528
M10	7	46	7.7	764	34	51.7	15.3	62.2	25.8	37.4	56.2	1.1	6.1	*u.d.*	*u.d.*	-50.1	-7.6	-1.8	5.5	0.70490
M16	4	5	7.5	4610	30	485.7	56.5	282.4	159.0	1098.1	317.5	145.3	7.0	0.1	0.5	-34.0	-6.0	*n.d.*	*n.d.*	*n.d.*
M17	6	2	7.4	1950	30	271.4	43.7	71.6	45.7	181.7	59.2	39.8	7.4	0.1	0.1	-44.2	-6.8	*n.d.*	*n.d.*	*n.d.*
M18	11	10	7.5	1910	33	305.7	24.5	54.9	42.2	175.1	97.1	2.7	12.2	0.1	*u.d.*	-38.1	-6.4	*n.d.*	*n.d.*	*n.d.*
M19	4	43	7.7	2440	31	127.9	21.5	180.2	97.2	479.6	85.3	6.8	5.1	*u.d.*	0.7	-40.8	-6.4	*n.d.*	*n.d.*	*n.d.*
M22	18	55	7.4	622	29	46.0	10.3	52.1	17.7	30.6	11.5	2.6	10.8	*u.d.*	0.1	-46.4	-6.8	21.9	*u.d.*	0.70577
M23	28	*l.d.*	7.3	500	31	40.1	7.0	33.5	14.6	20.5	22.0	6.6	10.9	*u.d.*	*u.d.*	-46.7	-6.8	3.8	13.7	0.70448
M24	23	*l.d.*	7.2	662	30	48.0	13.2	51.9	18.4	40.7	16.6	1.1	3.5	*u.d.*	*u.d.*	-47.1	-7.0	19.9	12.1	0.70449
M25	17	37	7.1	406	29	27.2	9.7	27.3	9.8	15.2	5.7	0.7	2.4	*u.d.*	*u.d.*	-44.9	-6.7	21.4	16.6	0.70450
M26	1	12	7.2	5600	30	848.1	23.1	94.2	74.7	1338.5	278.0	13.8	10.2	*u.d.*	1.4	-40.9	-6.4	22.0	15.0	0.70622
M27	20	24	7.6	491	29	77.7	9.6	48.7	15.6	24.8	38.4	15.7	9.7	*u.d.*	0.4	-36.7	-6.0	1.8	7.5	0.70638
M32	14	12	7.3	1416	30	158.5	7.9	97.8	48.6	155.2	29.6	3.9	4.4	0.1	*u.d.*	*n.d.*	*n.d.*	14.9	12.0	0.70612
M33	21	122	7.3	690	30	63.8	5.7	63.5	16.3	28.5	8.4	1.0	4.3	*u.d.*	*u.d.*	*n.d.*	*n.d.*	14.8	12.6	0.70748
M34	14	73	7.1	500	29	34.1	11.7	34.7	16.3	33.7	20.8	1.1	10.1	*u.d.*	0.3	*n.d.*	*n.d.*	8.1	7.3	0.70447
Deep groundwater (183-269 m in depth: production wells)																				
M1	6	*l.d.*	8.2	538	34	100.8	14.3	8.3	2.5	13.5	12.8	1.2	7.1	*u.d.*	0.4	-48.1	-7.3	15.9	15.2	0.70448
M3	3	223	8.5	613	35	126.8	13.4	2.9	0.4	51.7	22.9	1.6	8.1	0.1	0.1	-50.3	-7.8	20.6	15.4	0.70490
M5	4	190	8.6	609	35	122.3	12.6	1.5	0.3	31.9	28.7	1.1	9.2	0.1	0.2	-51.3	-7.9	21.2	15.0	0.70493
M7	4	269	8.0	591	32	79.4	27.3	25.6	8.8	10.1	19.6	0.5	19.8	*u.d.*	0.2	-48.9	-7.7	11.4	11.3	0.70631
M9	7	*l.d.*	7.7	542	30	46.5	12.5	40.3	18.9	11.7	8.5	1.0	9.1	*u.d.*	0.3	-51.9	-7.9	8.7	8.5	0.70474
M20	14	*l.d.*	8.3	853	33	167.9	23.3	9.8	1.7	63.6	14.3	1.4	4.7	*u.d.*	0.4	-39.2	-6.2	*u.d.*	7.1	*n.d.*
M28	18	183	8.1	746	32	151.9	17.1	8.9	3.1	43.8	14.2	1.0	2.6	0.1	*u.d.*	-45.3	-6.7	22.9	13.4	0.70476
M29	30	195	8.5	657	31	145.5	12.7	6.2	0.7	12.7	18.7	1.1	1.7	*u.d.*	0.2	*n.d.*	*n.d.*	4.5	8.0	0.70448
M30	25	183	8.4	708	34	154.7	13.1	7.2	1.0	12.3	10.5	1.0	1.3	*u.d.*	0.4	*n.d.*	*n.d.*	17.8	14.3	0.70447
M31	9	*l.d.*	8.3	1346	32	277.7	15.9	7.7	1.8	227.2	38.1	3.4	1.1	*u.d.*	*u.d.*	*n.d.*	*n.d.*	19.5	14.2	0.70487

l.d. = lack of detailed data
n.d. = not determained
u.d. = under the detection limit

Table 2: Analytical results for water samples reacted with fertilizers and detergents commonly used in Metro Manila

Name	Material	Na^+ mg/L	K^+ mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Cl^- mg/L	SO_4^{2-} mg/L	NO_3^- mg/L	As µg/L	Cd µg/L	Pb µg/L	$\delta^{34}S\text{-}SO_4^{2-}$ ‰	$\delta^{18}O\text{-}SO_4^{2-}$ ‰	$^{87}Sr/^{86}Sr$
Water reacted with fertilizers														
MNLF2	ammonium sulfate	*u.d.*	0.4	21	0.2	0.7	773	*u.d.*	0.3	0.2	0.6	0.8	10.1	*n.d.*
MNLF3	NPK fertilizer	2.0	101.0	24	1.0	94.8	384	3.2	5.2	1.0	0.3	-0.2	9.9	0.70589
MNLF4	NPK fertilizer	1.3	6.4	22	2.2	6.7	469	1.1	7.2	2.6	0.4	0.1	10.4	0.70697
average (*n = 3*)		**1.6**	**35.9**	**22**	**1.1**	**34.1**	**542**	**2.2**	**4.2**	**1.3**	**0.4**	**0.2**	**10.1**	**0.70643**
Water reacted with detergents														
MNLD1	powder detergent	278	0.6	22	0.4	2.3	150	*u.d.*	4.2	1.7	3.2	13.5	14.0	*n.d.*
MNLD2	powder detergent	256	0.7	22	0.3	1.9	267	*u.d.*	2.3	0.3	0.6	22.0	16.1	*n.d.*
MNLD3	powder detergent	286	0.3	22	0.4	2.0	303	*u.d.*	0.3	0.2	0.3	24.9	12.4	*n.d.*
MNLD4	powder detergent	293	0.5	22	0.2	1.7	330	*u.d.*	0.6	0.3	0.4	16.3	17.8	*n.d.*
average (*n = 4*)		**278**	**0.5**	**22**	**0.3**	**2.0**	**263**		**1.9**	**0.6**	**1.1**	**19.2**	**15.1**	

u.d. = under the detection limit

n.d. = could not determained